

The Analysis, Numerical Simulation, and Diagnosis of Extratropical Weather Systems

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Award #: N0001499F0068

LONG-TERM GOAL

My long-term goal is to contribute to the advancement of the observation, structural analysis, dynamical diagnosis, and numerical prediction of the life cycles of synoptic-scale and mesoscale weather systems, including the influence of planetary-scale, inter-annual and intra-seasonal variability on their evolution. These weather systems include: mid-latitude and arctic oceanic and land-falling cyclones, fronts and their associated cloud, wind, and precipitation systems; upper-level jet streams and clear-air turbulence, extreme topographic flows and their interactions with the ocean.

OBJECTIVES

My work over the past year has focused on four primary objectives: i) the direction, coordination and planning of THE Observing-system Research and *predictability experiment* (THOR*pex*), ii) the diagnosis and dynamical interpretation of research and operational targeted observations and the impact of these observations on 2-7 day weather forecasts, iii) the numerical simulation and observational validation of high-spatial resolution (~200 m; vertical and ~10 km; horizontal) numerical forecasts of lower-stratospheric inertia-gravity waves and associated turbulence, iv) the role of large-scale topography in the initiation of inertia-gravity waves and Rossby wave trains, and v) the life cycles and predictability of extratropical cyclones.

APPROACH

My approach toward achieving the above objectives has been to foster national and international scientific interactions, and by doing so, develop the research teams required to address the above complex objectives. The support that I have received through my ONR-sponsored grant (N0001499F0068) has been applied to my NOAA salary, visits with my collaborators, the publication of findings, THOR*pex* organizational meetings, and research presentations at national and international symposia, universities, and workshops.

The following identifies selected tasks related to my contribution THOR*pex* and Ongoing Research:

1. THE Observing-system Research and *predictability experiment* (THOR*pex*).

The primary goal of THOR*pex* is to improve operational short-range (0-2 day), medium-range (3-7 day), and extended-range (week-two) weather forecasts of high-impact weather through international collaboration between operational and research communities. In 2000 and 2001, Rolf Langland and I

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 30 SEP 2002		2. REPORT TYPE		3. DATES COVERED 00-00-2002 to 00-00-2002	
4. TITLE AND SUBTITLE The Analysis, Numerical Simulation, and Diagnosis of Extratropical Weather Systems				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) NOAA/Environmental Technology Laboratory,,325 Broadway,,Boulder,,CO, 80303				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT My long-term goal is to contribute to the advancement of the observation, structural analysis, dynamical diagnosis, and numerical prediction of the life cycles of synoptic-scale and mesoscale weather systems, including the influence of planetary-scale, inter-annual and intra-seasonal variability on their evolution. These weather systems include: mid-latitude and arctic oceanic and land-falling cyclones, fronts and their associated cloud, wind, and precipitation systems; upper-level jet streams and clear-air turbulence, extreme topographic flows and their interactions with the ocean.					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 6	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

coordinated the preparation of the THOR p ex preliminary Science Proposal presented by the THOR p ex/International Science Steering Committee (ISCC) to the World Meteorological Organization/World Weather Research Program (WMO/WWRP) and Working Group on Numerical Experimentation (WGNE). This effort set the stage for THOR p ex becoming a priority Program of the WMO and US Weather Research Program. The THOR p ex Science Proposal was endorsed by the WMO/WWRP and WGNE in October 2001. During 2002, THOR p ex established its International Core Steering Committee (ICSC) with representatives from Australia, North America, Europe, and Asian. The current International Science Steering Committee (ISSC) has representatives from ~14 nations and oversees the development of THOR p ex Science Plan. The ONR support provided to me through this grant contributed to ONR's participation and leadership in the development of THOR p ex.

Critical elements in my contribution to the development of THOR p ex include:

Science directorship planning and leadership of THOR p ex: I currently serve as Co-chair (with Alan Thorpe, Univ. Reading UK) of the THOR p ex/International Science Steering Committee and as an *ex-officio* member of the THOR p ex/International Core steering Committee. The accomplished tasks include:

- Preparation and presentation of the THOR p ex Science Proposal to the WMO/WWRP in Offenbach, Germany; October 2001, (http://www.mmm.ucar.edu/uswrp/thorpex/THORpex_wmo.pdf),
- Organizing and convening the First THOR p ex International Workshop and International Science Steering Committee Meeting, Potomac, MD, 18-20 March 2002.
- Preparing the Report on the Current Status of THOR p ex, July 2002, (http://www.mmm.ucar.edu/uswrp/thorpex/THORpex_Status_Report_final.pdf)
- Preparing the updated THOR p ex Program Overview, (<http://www.mmm.ucar.edu/uswrp/programs/thorpex.html>),
- Staffing and tasking the Co-chairs of the four THOR p ex Sub-program Teams for preparation of the THOR p ex Science Plan (due Dec. 2002),
- Planning for the THOR p ex Science Plan Development Workshop, December 3-5 Monterey, California, to be hosted by The US Weather Research Program and NRL/Monterey.

2. Ongoing Research

My ongoing research interests and contributions include:

The role of diabatic processes in the phase-locking of a tropopause-based potential- vorticity anomaly and surface cyclone development. This is a study of the January 2000 eastern US snow storm. Results will be presented at the September 2003 Cyclone Workshop, Val Morens, Canada; collaborative effort with Fuqing Zhang (Texas A&M).

The excitation of vertically-propagating inertia-gravity waves during extra-tropical jet-stream development. This includes observations from the ONR-sponsored NORPEX 1998 field experiment over the north Pacific ocean and mesoscale numerical simulations with COAMPS and MM-5. This

effort shows the ability of mesoscale models to predict gravity waves at jet-stream levels and within the lower stratosphere. This is collaborative effort with Andreas Dörnbrack (DLR), Oberpfaffenhofen, Germany, and James Doyle (NRL/Monterey). Results from this study will be presented as an invited paper at the December 2002, AGU Meeting, San Francisco, California.

An assessment of radiosonde/dropsonde representativeness error on operational numerical weather prediction. For this study, ONR supported the selective doubling the spatial resolution of targeted dropwindsondes during the January-March 2002 Winter Storm Reconnaissance program, Honolulu, Hawaii. Sensitivity experiments were performed with the ECMWF forecast model for three cases that showed that forecast error varied by up to 50% when alternate dropsondes were assimilated within NCEP targeted regions. This is a collaborative effort with Martin Leutbacher (ECMWF) and Zoltan Toth (NCEP). I was responsible for coordinating this field operations with NCEP and flew on the NOAA/G-4 to supervise deployment of supplemental dropsonde soundings.

The role of large-scale topography on the predictability of cyclogenesis in the lee of Greenland and the associated topographic excitation of downstream Rossby-wave trains. This is a collaborative effort with Simon Low-Nam (NCAR/MMM), Andreas Dörnbrack (DLR, Germany), Haraldur Olafsson (Icelandic Met. Service), and Piotr Smolarkiewicz (NCAR/MMM). Results from this study were presented at AMS/Mountain Met. Conference, Salt Lake City, Utah, August 2002, and were featured in my invited paper presented at the January 2002, *AMS/Richard J. Reed Symposium: A half Century of Progress in Meteorology*.

Wake flows in the lee of Iceland. This study uses QUIKSCAT sea-surface wind observations, high-resolution numerical forecasts, and theoretical diagnostics to describe a low wind speed wake and associated flanking low-level jets for an extreme (50 ms⁻¹) wind event over Iceland. This is a collaborative effort with Haraldur Olafsson (Icelandic Met. Service). Results were presented at AMS Mountain Meteorology Conference, Salt Lake City, Utah, August 2002.

Breaking gravity waves over Greenland. This represents a continuation of my work with James Doyle (NRL/Monterey). Results include idealized and actual simulations verified against mesoscale analyses of FASTEX dropsondes over Greenland (journal publication, in preparation).

*Observations and numerical simulations from the **Severe Clear-Air Turbulence encounters with Commercial Air Traffic (SCATCAT) turbulence field experiment.*** This work is an ongoing collaboration with NOAA/FSL, NCAR/ATD, NCAR/MMM, and NRL/Monterey. Analysis and simulations are currently underway to study the 17 February 2001 turbulence event measured with high-spatial-resolution (40 km) dropsondes and flight-level measurements taken with the NOAA/G-4 research aircraft flight from Honolulu, HI. The numerical simulations are being carried out by Jim Doyle (NRL/MRY) and Todd Lane (NCAR/MMM). I coordinated and participated in directing the G-4 observations and is responsible from the analysis of the NOAA/G-4 observations.

WORK COMPLETED

The work completed this year is described in the results below.

RESULTS

The following are selected significant research results from this year appearing (to appear) in the formal and informal literature (see PUBLICATIONS, below):

Initial condition sensitivity and error growth in forecasts of the 25 January 2000 East Coast snowstorm. This is one of the first studies to demonstrate that regions of forecast sensitivity to initial-condition (analysis) errors propagate with the group velocity of expanding Rossby-wave packets

The assimilation of TOMS total ozone for improved prediction of extratropical weather systems. This collaborative effort with Jang, Kun-Il, X. Zou, Q. Zhao, A. Kruger presents a method and results of incorporating TOMS satellite observations of total columnar ozone into the data assimilation and prediction of extratropical cyclones. Results suggest that the assimilation of satellite measurements of ozone can improve the skill of operational weather forecasts.

Large-amplitude gravity-wave breaking over the Greenland lee and the subsequent formation of downstream synoptic-scale tropopause folding and stratospheric-tropospheric exchange. The most important findings in this study are: i) the major influence of large-amplitude topographic gravity waves in the development of downstream tropopause based jet streams and subsequent explosive lee cyclone development; ii) the topographic excitation of Rossby-wave packets by Greenland and their effect on forecast skill over Europe and North Africa on 24-72-h time scales; iii) the role of topographic gravity waves in the exchange of air and trace constituents between the stratosphere and troposphere..

IMPACT/APPLICATION

The work that my collaborators and I have been carrying out is at the frontiers of meteorological research and operational forecasting. We have made contributions to: i) the development of THOR_{pex}, ii) targeted observing strategies and identification of sensitive regions from which forecast errors originate, iii) arctic mesoscale flows, and iv) four-dimensional data assimilation. The presentation of our findings in the articles, reports, scientific meetings, university and Agency seminars, and THOR_{pex} and USWRP workshops has had a significant impact in shaping future directions in atmospheric observing systems, and advancing basic knowledge of synoptic-scale and mesoscale weather systems, their associated dynamical processes and predictability. The most important application of our work is its contribution to the improvement of operational weather forecasting.

TRANSITIONS

My collaboration with Rolf Langland (NRL/Monterey) and other scientists has contributed to the accelerated national and international planning for THOR_{pex}. I hope to continue to represent and assist ONR in further development of THOR_{pex}, and to participate in future ONR Research Initiatives on the predictability of weather systems

My continuing work with Jim Doyle on the simulation and field study validation of complex mesoscale flows has been used to confirm the capabilities of the Navy operational mesoscale prediction system (COAMPS). These results are of critical value for development and verification of COAMPS.

PUBLICATIONS

Langland, R.H., **M.A. Shapiro**, and R. Gelaro, 2001: Initial condition sensitivity and error growth in forecasts of the 25 January 2000 East Coast snowstorm. *Mon. Wea. Rev.*, **130**, 957-974.

Jang, Kun-Il, X. Zou, Q. Zhao, A. Kruger, and **M. Shapiro**. 2002: Incorporating TOMS ozone data into the prediction of the Washington January 2000 winter storm. *J. Appl. Meteorol.* (revised).

Shapiro, Melvyn A., S. Low-Nam, H. Olafsson, J. Doyle, and P. Smolarkiewicz: Large-amplitude gravity-wave breaking over the Greenland lee and the subsequent formation of downstream synoptic-scale tropopause folding and stratospheric-tropospheric exchange. *10th Conference on Mountain Meteorology*, Salt Lake City UT., 126-129.